Low insertion losses and high drop efficiency photonic crystal filter for advanced telecom modulation formats

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Abstract: A 2D photonic crystal 3-ports filter with 6 dB bus insertion losses and drop efficiency of 47 % is reported. Error-free operation with low penalty (<0.5 dB) for OOK and DQPSK modulation formats is demonstrated.
OCIS codes: (230.5298) Photonic crystals; (230.7408) Wavelength filtering devices

1. Introduction

During the last years, photonic crystals (PhC) have been used to realize optical devices for different applications. They have been demonstrated as a promising candidate for realizing large integration scale devices for all-optical communication networks [1-3]. Extremely compact PhC filters for optical communications have been proposed and demonstrated in the literature, with promising results, such as add-drop filter [4], with system assessment at 10 Gbit/s [5], channel drop filter [6-9], bandstop filter [10] and bandpass filter [11]. Here we report on the single-channel performances and capabilities of PhC-based drop filter, with 28 Gbit/s OOK (On-Off Keying) signal filtering. Moreover, to the best of our knowledge, we present for the first time, 56 Gbit/s DQPSK (Differential Quadrature Phase Shift Keying) signal filtering through PhC-based filter.

2. Photonic crystal technology

The PhC filter is fabricated in III-V material (GaAs) and consists in 3-ports, single resonator design, having a 2D triangular lattice structure [12]. To investigate the filter performance and optimize the different geometrical parameters, Coupled Mode Theory (CMT) and Three Dimensional Finite Difference in the Time Domain (3D-FDTD) techniques have been used. As reported in [13], for a single cavity based filter a maximum drop efficiency of 50 % can theoretically be obtained. In this configuration, the achievement of high drop efficiency is pursued by adjusting the transmission properties of the bus and drop waveguides and the cavity to waveguides coupling strength. This modification can be induced, for example, by narrowing the PhC waveguide (to reduce the cut-off wavelength) or by using a different pitch of the PhC waveguides in the region close to the resonator (realizing what is usually named a tapered waveguide). If these perturbations are introduced properly, the light at the working-wavelength could be very efficiently switched from bus to drop waveguide.

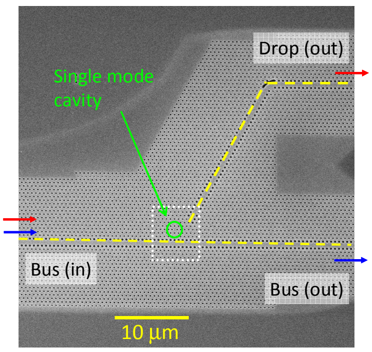

Fig.1. SEM picture of the PhC-based filter with one drop channel

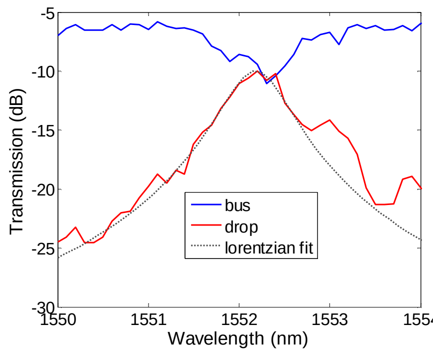

Fig.2. Transmission spectra of bus (blue) and drop (red) ports. Dashed line : Lorentzian fit.

Fig.1 shows SEM picture of the filter. The single line defect (dotted line) is introduced as a waveguide. The coupling of the cavity (circle) to the waveguide is optimized in order to reach the optimal drop efficiency. In order to reduce the total insertion losses and decrease Fabry-Perot oscillations, we have improved the fiber to PhC coupling using integrated mode adapters [14] (loss ~ 2.5 dB per face in TE mode at 1550 nm). The total insertion losses, from the input fiber to the output fiber, are of about 10.5 dB on the drop port and 6 dB on the bus one. The drop efficiency is evaluated to be 47 %. The transmission of the drop port is shown on Fig.2. By fitting the transmission curve with a Lorentzian, a 3 dB bandwidth around 0.8 nm is measured, as predicted by coupled mode theory. We notice a good fitting on the left side of the resonance but distortions on the right side of the transmission spectrum, which we think to be due to fabrication imperfections. Cross-talk isolation at 500 GHz from central frequency is better than 20dB.

3. System assessment

System assessment was performed using NRZ signal at 28 Gbit/s and bit error rate (BER) measurement reveals very low penalty (<0.5 dB) (Fig.3). We also evaluate the possibility to transmit NRZ-DQPSK signal at 56 Gbit/s into the device, assessed through bit-error rate measurements, revealing very low penalty (<0.5 dB), at BER of 10^{-9}, after passing through the device on the drop channel on either the in-phase (I) and the quadrature-phase (Q) component of the DQPSK signal (Fig.3). Additionally, we investigated also the evolution of performances as a function of signal wavelength shift respect to cavity resonance (Fig.4). We can notice penalties when signal is slightly shifted to the right of the resonance, probably due to transmission distortions, and that impact is the same for both modulation formats.

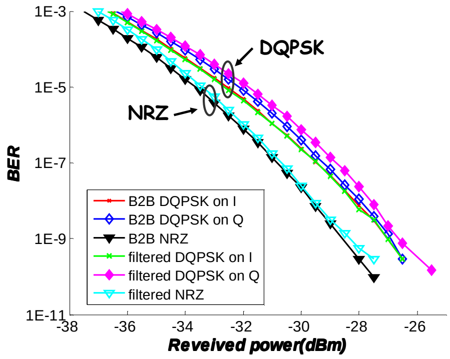

Fig.3. Bit error rate measurements of OOK and DQPSK signals through PhC drop filter.

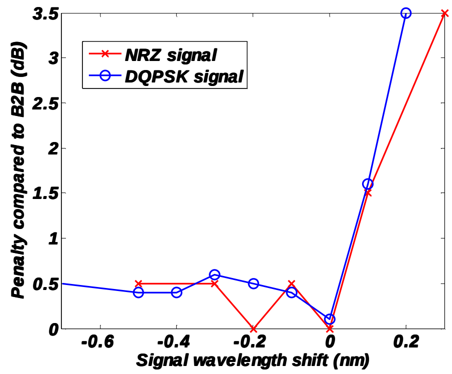

Fig.4. Evolution of penalty as a function of signal wavelength compared to cavity resonance.

4. Conclusion

We have developed an optical filters based on semiconductor photonic crystals technology. We have reported the achievement of the lowering of the total insertion losses down to 6 dB for the bus port and 10.5 dB for the drop port, the reaching of a drop efficiency up to 47 % and 20 dB cross-talk isolation (at 500 GHz). To our knowledge, we have performed for the first time PhC-based filter system assessment through BER measurements with 28 Gbit/s OOK and 56 Gbit/s DQPSK data signals, revealing error-free operation with no additional penalty (<0.5 dB) after the transmission through the drop filter. Additionally, we highlight the impact of transmission distortions in governing the drop filter performances. The results outlined here demonstrate that such a filter has spectral behavior compliant with requirement of coarse-wavelength-division-multiplexing (CWDM) systems.

5. References

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6. Acknowledgement

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